A strategic study on biodiversity conservation in Xishuangbanna

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Abstract: Xishuangbanna harbors valuable tropical rainforests with abundant biodiversity and it is acknowledged as a treasure house of wildlife. By describing the characteristics of its physical geography, the authors analyzed the habitat complex. The major vegetation types and rare wildlife were systematically studied to indicate the major elements and great value of the biodiversity. The present status of general biodiversity conservation was briefly appraised to reveal the potential crises and problems in the conservation practice. Based on the theories and experience borrowed from modern conservation biology and innovations at home and abroad, 4 primary strategies were accordingly suggested to establish a beneficial mutual-improvement mechanism for the better conservation so that the biodiversity conservation and utilization can be properly integrated, the local people's livelihood effectively uplifted and their over-dependence on the resources relatively lessened.

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Introduction

Forests are major habitats of terrestrial wildlife species, whereas tropical rainforests are the areas most abundant in biodiversity in the world. However, it was reported by FAO in *The World Forest Facts* that totally about 11.3 million hm^2 of the world forests were destroyed, and another 18 million hm^2 of valuable tropical rainforests out of the total 1.16 billion hm^2 all over the world were damaged to some extent annually. A report from UNEP also said that 12% of mammals and 11% of birds of the world were endangered of extinction and some 150~200 wildlife species disappeared every day. Today when man is faced with the global forest reduction and ever-increasing aggravation of ecological challenges, biodiversity is gradually lost in imminent danger and its conservation confronts potential crises as forests are exposed to the effects of poor management and unbridled development due to man's disturbance. Thus, it is very urgent that new strategies be studied for the effective biodiversity conservation in Xishuangbanna since it is a specific area with top priority of global significance.

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Physical geographic characteristics

Xishuangbanna is located in both the south of Yunnan and the northernmost edge of the tropics of the world as one of the most important areas abundant in tropical rainforests and biodiversity. It is a large basin-like prefecture, covering 197 000 km^2, approximately 5% of the total area of Yunnan or 2‰ of that of China. The area is bordered on all the four sides by lofty highlands that keep off cold air currents from the north with only an exception of several gaps in the south. It is from these gaps that southwesterly monsoon from the Indian Ocean comes and forms a typical tropical climate and plentiful precipitation. As the most important forest areas in the prefecture, the Xishuangbanna Nature Reserve (XNR) is composed of five isolated sections, covering the dominant landform of some low mountains and occasional geography of basins. The highest land surface is 2 007 m while lowest section is 580 m above sea level. Owing to its specific topography, Xishuangbanna Nature Reserve remains in the tropical monsoon zone despite its upper locality at 21°10'~22°24' N. It has a mountain climate with vertical elevation differences in temperature. It is climatically defined as the monsoon tropics of sub-humid type with its major part in the northern tropics and southern subtropics. The XNR is strongly influenced by the south branch jet flow of the westerly, thus making winters mild and dry.

Investigations and statistics show that light-energy-utilizing ratio of the tropical seasonal

rainforests is 1.01%. As the areas within 1 000 m above sea level belong to the northern tropics, the temperature limit of tropical seasonal rainforests is the same as that of the northern tropics. The active accumulated temperature is 7 500 °C and the lowest mean monthly temperature is 15°C whereas the annual minimum rainfall is 1 500 mm. Owing to its complex geography, specific location, natural habitats and special climates, the area holds abundant vegetation types and diverse wildlife species.

Major elements of the biodiversity

Situated at the very juncture of varied florae and faunae with abundant biodiversity, Xishuangbanna not only has diverse vegetation types including tropical rainforests, tropical monsoon forests, subtropical broad-leaved evergreen forests, broad-leaved deciduous forests, temperate coniferous forests, bamboo forests, shrub forests and herbosa, but also harbors over 3 500 species of higher plants, 700 species of higher animals and 1 500 species of insects. The number of these species makes up 21%, 40.3% and 15% of the total of Yunnan, or 13% 24% and 6% of that of China, respectively. Among the plants, there are 35 epibiotic species of tertiary palaeotropical ones, 150 species of endemic ones, 30 species of wild protophytes and 58 species of endangered ones listed as major protected ones of the nation. There are over 102 species of mammals including over 270 elephants and 42 tigers, 423 species of birds, 38 species of amphibians, 60 species of reptiles and 100 species of fish, 109 of which are endangered species listed as major protected ones of the nation. Besides, there are over 1 500 species of insects with the species of butterflies being the most colorful, beautiful, multitudinous and famous. Owing to its specific locality, good environment, beneficial climates and rich biodiversity, Xishuangbanna is acknowledged as a treasure house of wildlife and valuable gene bank worth researching and protecting intensively although it covers only 5% of the total area of Yunnan Province, or 2‰ of that of China. Based on the background surveys of the forest resources made so far, the major elements of the biodiversity in this special area are systematically studied in order to show the rich biodiversity and great conservation value. The major elements for the biodiversity conservation in this area are described in 4 aspects, i.e., the biodiversity in vegetation types, rare plants, wild animals and insects as follows.

Biodiversity in vegetation types

Under the 8 most important vegetation types such as tropical rainforests, tropical monsoon forests, subtropical broad-leaved evergreen forests, tropical broad-leaved evergreen forests, broad-leaved deciduous forests, temperate coniferous forests, bamboo forests, shrub forests and herbosa, there are altogether 13 subtypes and 29 formations. Among all these, the type of tropical rainforest is composed of 2 subtypes, the subtype of seasonal rainforests and mountain rainforests. The former one involves 4 formations of forests, i.e., *Dipterocarpus turbinatus* forests, *Vatica xishuangbannaensis* forests, *Terminalia myriocapa--Pometia tomentosa* forests, and *Parashorea chinensis* forests while the 3 of the latter are *Semecarpus reticulata--Phoebe nanmu--Pouteria grandifolia* forests, *Podocarpus imbricatus--Lithocarpus corneus* forests and *Alstonia scholaris--Nephelium chryseum* forests. The type of tropical monsoon forests consists of 3 subtypes including that of semi-evergreen monsoon forests, deciduous monsoon forests and limestone-hill monsoon forests. The first one is composed of 3 formations, i.e., *Ficus fulva--Chukrasia tabularis var. velutina* forests, *Macaranga denticulata* forests and *Trema orientalis* forests. The second one has 2 formations including *Erythrina stricta--Bauhinia variegata* forests and *Bombax malabarica* forests whereas the third holds the other 2 involving *Tetrameles nudiflora--Cleistanthus saichikii* forests and *Cycas pectinata--Bauhinia variegata* forests. The type of subtropical broad-leaved evergreen forests is divided into 2 subtypes. The first one has 5 formations, i.e., *Castanopsis carlesii var. spinulosa–Castanopsis echidnocarpa* forests, *Lithocarpus truncatus--Phoebe nanmu* forests, *Castanopsis mekongensis--Lithocarpus truncatus* forests, *Lithocarpus* spp.*--Sladenia celastrifolia* forests, and *Lithocarpus fenestratus--Cyclobalanopsis kerrii* forests, while the second one has only 1 formation, i.e., *Cyclobalanopsis chapensis* forests. Under the type of broad-leaved deciduous forests, there is 1 formation of *Alnus nepalensis* forests in the subtype of warm temperate broad-leaved deciduous forests. Under the type of warm temperate coniferous forests, there is 1 formation of *Pinus kesiya var. langbianensis* forests in 1 subtype of warm tropical coniferous forests. The same thing happens in the type of bamboo forests, under which there is 1 main formation of *Dendrocalamus strictus* groves in its only 1 subtype of warm tropical bamboo forests in XNR although there are more than 80 species and 20 varieties or mutations in 18 genera of bamboos nearby. In the type of shrub forests, there are 2 subtypes of riverbank shrub forests and hillock shrub forests. In the first subtype there is 1 formation of *Homonoia riparia--Cleistocalyx operculatus* forests while in the second there are 2 formations, including that of *Cratoxylum cochinchinensis--Wendlandia* spp. forests and *Quercus acutissima* forest. In the type of her-

bosa, there is 1 subtype of grasses, under which there are 3 formations, i.e., the formations of *Imperata cylindrica var. major--Themeda gigantea var. villosa* herbosa, *Saccharum arundinaceum--Neyraudia reynaudiana* herbosa and *Miscanthus floridulus--Miscanthus sinensis* herbosa. All these vegetation types form the major habitats that harbor the wildlife of the area.

Biodiversity in rare plants

In this specific area, there are more than 355 rare plant species belonging to the following 4 major categories. Firstly, there are 35 species of tertiary palaeotropical relict plants including *Angiopteris* spp., *Cyathea spinulosa, Cycas pectinata, C. siamensis, Podocarpus imbricatus, P. wallichiana, P. fleuryi, P. neriifolus, Sladenia celastrifolia, Magnolia henryi, Cenocentrum tonkinense, Camptotheca acuminata, Borthwickia trifoliata, Homalium laoticum, Chaydaia rubrinervis, Silvianthus bracteatus, Pygeum topengii, Pittosporopsis kerrii*, etc. These species belong to 12 genera out of the 20 existing epibiotic genera of plants all over the world. Secondly, there are 150 species of endemic plants, including *Parashorea chinensis, Vatica fleuryana, Manglietia wangii, M. microgyna, Magnolia delavayi, Polyalthia cheliensis, P. verrucipis, P. litseifolia, Litsea dilleniaefolia, Homalium laoticum, Pellacalyx yunnanensis, Horsfieldia pandurifolia, H. tetratepala, Myristica yunnanensis, Pterospermum yunnanensis, Pt. Menglunensis, Nyssa yunnanensis,* etc. Thirdly, there are 130 species of rare plants including *Michelia hedyosperma, Paramichelia baillonii, Litsea pierrei, L. lancifolia, L. magnoliifolia, Lagestroemia intermedia, Heliciopsis terminalis, Manglietia fordiana, Cryteronia paniculata, Tetrameles nudiflora, Mesua nagassarium, Terminalia myriocarpa, Anogeissus acuminata, Carallia lanceafolia, Dalbergia fusca, Dipterocarpus turbinatus, Antiaris toxicaria, Sloanea tomentosa, Maytenus hookeri,* etc. Fourthly, there are 30 species of wild protophytes and kindred plants of modern cultivars such as *Camellia sinensis var. assamica* Kitam., *C. oleifera var. confusa, Citrus grandis, Litchi chinensis, Oryza minuta, Oryza meyeriana subsp. granulata, Amomum villosum, A. aurantiacum, Mangifera sylvatica, Musa wilsonii, Panax zingiberensis,* etc. Among all the above-mentioned species, 58 endangered species are listed as the major protected ones of the nation. Besides, there are over 1 572 species of cash plants including 782 species of medical plants in 146 genera belonging to 139 families (Xu *et al.* 1987).

Biodiversity in wild animals

In Xishuangbanna, there are altogether 102 species of mammals that belong to 74 genera in 23 families of 9 orders, making up 41.32% of that of Yunnan, i.e., 21.7% of the total species of China. The major species include smaller animals like *Tupaia belangeri chinensis, Hylomys* sp., *Crocidura russala rapax, Eonycteris spelaea, Eonycteris spelaea, Taphozous melanopogon melanopogon, Parascaptor leucurus, Hipposideros armiger armiger, Megaderma lyra snensis, Myotis mystacinus,* etc. They include larger animals such as *Macaca mulatta mulatta, Nycticebus coucang bengalensis, Manis pentadactyla auritus, Canis lupus, Hylobates concolor leucogenys, Ailurus fulgens styani, Selenarctos thibetanus thibetanus, Prionodon pardicolor, Mustela sibirica, Panthera tigris corbetti, Sus scrofa jubatus, Eiephas maximus indicus, Tragulus javanicus williamsoni, Muntiacus muntjak vaginalis* and *Bos gaurus readei.* Besides, they also consist of some other smaller animals in *Lagomorpha* and *Rodentia* including *Atherurus macrourus stevensi, Hylospetes alboniger orinus, Callosciurus erythraeus hendeei, Apodemys draco orestes, Rhizomys pruinosus latouchei, Eothenomys miletus miletus, Lepus comus,* etc. Among all the wild animals found in this area, 15 species including *Viverra megaspila megaspila, Pipistrellus minus minus, Bos banteng, Belomys pearsoni biandus, Petaurista philippensis lylei*, etc. and 12 subspecies are new records to mammalian fauna in China while *Arctictis binturong menglaensis* is new to science. The new record subspecies include *Hipposideros larvatus grandis, Cuon alpinus adustus, Melogale moschata taxilla, Arctonyx collaris dictator, Viverra zibetha surdaster, Viverricula indica thai, Sus scrofa jubatus, Belomys pearsoni blandus, Hystrix hodgsoni klossi,* etc.. In short, the mammalian fauna is characterized by its multitudinous species, distinct tropical fauna composition, rich arboreal animals, very few endemic species and many rare species, showing its evident similarity to that of the tropics in Southeast Asia.

In the avifauna of Xishuangbanna, there are 423 species and subspecies of birds belonging to 52 families in 18 orders with 319 species and subspecies belonging to oriental realm and 48 belonging to Palaearctic realm, i.e., 39.8% of the total species of Yunnan (Yang *et al.* 1990). Among the 423 species, 299 are residents, 51 are summer migrants, 52 are winter migrants, 21 are passing birds and 45 are endemic ones, most of which are insect destroyers. With little vertical distribution, the avifauna is characterized by the mixed inhabitation of predominant elements of the Oriental Realm, cosmopolitan elements, and a few elements of the Palaearctic Realm.

Among herpetological animals in Xishuangbanna, there are 38 amphibian species and subspecies belonging to 17 genera in 8 families of 3 orders, and 60 reptile species and subspecies belonging to 40 gen-

era in 14 families out of 3 orders respectively. Among these amphibians and reptiles, *Megophrys lateralis, Hemiphyllodactylus yunnanensis, H. typus aurantiacus, Pareas macularius, Natrix aequifasciata, Amphiesma venrringi, Rana verrucospinosa, R. livida,* and *Cyclemys dentata* are new records at various levels whereas *Ophryophryme pachyproctus* is a new species. The herpetological fauna is characterized by its predominant elements of Oriental Realm and few elements of the Palaearctic Realm.

Known as a treasure house of fish resources, Xishuangbanna holds 100 fish species in 54 genera in 18 families that make up 27% of total species, 40% of total genera and 69% of total families of Yunnan. In Xishuangbanna alone, there are 75 endemic species in 18 endemic genera belonging to 4 endemic families of *Akysidae, Gyrinocheilidae, Pangasidae* and *Schilbeidae,* all of which show a high percentage of unique endemism in China. Besides the new species of *Sikukia flavicaudata*, there are 8 major rare species including *Gyrinocheilus aymonieri, Tor tor sinensis, Labeo dyocheilus, Bagarius yarrelli, Pseudechenis sulcatus, Wallago attu, Pangasius sanitwangsei* and *Tetraodon leirus.* Considering that the above-mentioned endemic families and genera are also distributed in the Southeast Asian Peninsula and India, the fact shows that the area is more closely related to Vietnam, Laos, Myanmar, and India than any other parts of China are to these neighboring countries in fish faunal distribution.

Biodiversity in resource insects

The insect fauna in Xishuangbanna belongs to the Oriental Realm in which China's insect species are found. There are more than 1 500 species of insects belonging to 830 genera in 76 families in 15 orders with the species of butterflies being the most multitudinous and famous. Owing to the differences in climates and vegetation types, the insect populations vary from place to place. The area is divided into 3 vertical zones of insect distribution including the tropical rainforest and monsoon rainforest zone which is the major component with the most complicated forest vegetation types in the world, monsoon broad-leaved evergreen forest and deciduous forest zone and *Pinus kesiya var. langbianensis* forest zone. There are 4 major characteristics of the insects in the area: (1) rich palaeotropical termites; (2) abundant large-sized butterflies and moths; (3) fast-growing viability and multi-generation-prolonging vitality and (4) multitudinous rare and endemic species. There are 172 large-sized butterfly species in 107 genera in 8 families and 60 moth species, all of which are both colorful and beautiful. In short, the above-mentioned biodiversity is the major elements in the conservation, and it can be seen that Xishuangbanna holds both diverse wildlife species to be carefully protected and attractive biodiversity landscapes to be intensively utilized.

Conservation condition appraisals

As shown above, there are over 3 500 species of higher plants, of which, 35 are epibiotics of tertiary palaeotropical plants, 150 endemic ones, 30 wild protophytes and kindred plants of modern cultivars and 58 are endangered ones listed in the major protected ones of the nation. There are over 700 species of higher animals, and 109 of which are endangered species listed as major protected ones of the nation, and over 1 500 species of insects with the species of butterflies are the most multitudinous and famous. Among all the above, the rare endangered species and epibiotics compose the most important elements to be carefully conserved.

Generally, the biodiversity in Xishuangbanna has been well preserved after the establishment of XNR. However, since XNR scatters in 5 isolated locations, destruction incurred to the forests of the area has still caused decrease, degradation and islandization of the habitats. Meanwhile the biodiversity conservation often confronts challenges due to the high frequency forest fires, general lacks of qualified protectors, frequent insufficiency of conservation funds, poor means of forest management, bad attacks of forest pests and over-dependence of local residents on forest resources. Fuel wood consumption, slash-and-burn agriculture, illegal reclamation of forested lands, irrational logging, and poaching of wild animals have become major impediments to effective conservation because the biodiversity is gradually lost as forests are exposed to man's disturbances. It is therefore urgently necessary that new protection measures be taken instead of the inefficient traditional ones for the purpose of effective biodiversity conservation, so that the following strategies are suggested by borrowing certain theories from modern conservation biology and successful innovations at home and abroad.

Biodiversity conservation strategies

The following 4 strategies are carefully designed and suggested to meet the needs of effective conservation of physical environment and biodiversity as well as socioeconomic development of the local rural communities by treating the contradictions between the biodiversity conservation and utilization of the area according to the practical circumstances.

Technology innovation strategy

In order to monitor the population dynamics of any

major wildlife species including the conditions of the population and their biohazards like forest fires and pests, it is necessary a natural resource information system (NRIS) or geographic information system (GIS) be established by XNR for effective monitoring, decision and management. With greater intensity of inbreeding within a small population, its genetic heterozygosis decreases from generation to generation so frequently that the fitness of the population decreases, and this always causes a final extinction of the population. Investigations on the small population viability probability of various wildlife species therefore need very urgently to be enhanced since the destiny of a species depends ultimately on the fate of all the small populations of the same species. The minimum size for a livable population of all the species needs to be decided by further investigations and profound researches with the help of the NRIS or GIS. Besides, it is important that the palliation of species extinction rates especially that of the families and genera with only one species should be emphatically studied. The habitat fragmentation, dynamic course of niche shifts, habitat heterogeneity, isolating extent of habitat spots, effects of edge and islandization, population survivorship and extinction dynamics, etc. should also be monitored and studied respectively. The localities, sizes, shapes and network connection of various sections should be profoundly approached, effective fire mantles and proper habitat corridors should be established so that the effects of habitat edges and fragmentation can be lessened. If any of the most important species fails to grow well in its original place, it should be removed and conserved in some other optimum habitats according to the experiments and plan made meticulously in advance. Only by implementing the technology innovation strategies in this field, can all the above tasks be fulfilled and objectives realized.

Development innovation strategy

Theoretically, the conservation and utilization of nature reserves are two major aspects to which special attention is paid by many scholars, managers and naturalists. Since it is a famous scenic spot of international level and both the natural environment and biodiversity landscapes have strong appeal to visitors, Xishuangbanna enjoys exceptional advantages to designate certain sections for recreation. This is not only able to meet the needs of the provincial tourist planning, but also able to enhance the conservation of environment and biodiversity including that in NXR itself for its further development. An overall planning for developing tourism in NXR has also been adopted so that 10 recreation spots have been planned in the nature reserve, covering 2 500 hm^2., i.e., 1.04% of the total, and the spots including Sanchahe, Lushilin and Wangtianshu have gradually opened to the tourists. Although some good results have been obtained, it is still necessary to pay further attention to the following aspects: (1) developing ecotourism intensively; (2) reducing the villagers' over-dependence on the forest resources by admitting some of them in the ecotourism; (3) offering good conditions for scientific researches; and (4) taking effective measures to improve the environment (Chen *et al.* 1998).

Management innovation strategy

Since ecotourism is an environment-based trade, good education in ecological ethics and effective conservation of the environment and biodiversity are very important. Therefore ecotourist development lies greatly in good implementation of ecological priority strategy besides the above two strategies so that physical environment and biodiversity can be efficiently protected and utilized. In order that the strategic objective is effectuated, all the decisions from macro-strategies to micro-activities in tourism, agriculture and some other industries should legally accord with the fundamental principles of ecological priority. Fuel wood consumption should be decreased by improving both the livelihood and energy sources of the rural communities. Illegal reclamation of forested lands, irrational logging, poaching of wild animals and slash-and-burn agriculture should be strictly banned according to various laws and regulations. In developing ecotourism, its two subsystems should be used differentially though both the non-consuming tourism and consuming tourism belong to ecotourism. The former should be energetically advocated and supported by hiking, sightseeing, mountain-climbing, photographing wild animals, sketching from nature, investigating wildlife, exploring caves, floating, watching birds, butterflies, flowers, fish, etc. The latter needs carefully controlling because of its consuming activities involving hunting, fishing, camping, specimen collecting, etc. It is necessary that more attention be paid on intensive exploitation of the intangible humanity landscape resources including various colorful ethnical and forest cultures. Not only should such decisions be made according to the ecological priority principles, but also the income from rational biodiversity utilization including ecotourism should partly be used to protect the ecological environment and biodiversity. In this way, sustainable development of rational biodiversity utilization including ecotourism can be profitably realized with better conservation and utiiization of both the natural environment and biodiversity (Pu 1998).

Manpower innovation strategy

As the conservation and management of the bio-

diversity in Xishuangbanna are hampered by a lack of qualified workers at various levels, projects should be implemented to strengthen the role of Southwest Forestry College (SWFC) as a major supplier for training large-calibered scientists and technicians at academic, professional and technical levels. For a long-term purpose, SWFC should be strengthened in training capacity to make its greater contribution to both the environment conservation including biodiversity by forming adequate qualified manpower and sustainable development of physical environment, natural resources and social economy. This should also be supported by training the managers for their organizing and implementing various effective projects involving participation of the local people in the rural communities in social forestry, sustainable uses of lands, environment protection and ecotourism for the improvement for their livelihood. Meanwhile, the college should strengthen its didactic capacity for the study programs in the conservation of natural resources, development of multipurpose forestry, and management of buffer zones, ecotourism, national parks, nature reserves, etc. Advanced theories in conservation biology, various innovations, knowledge-based economics, economic globalization, etc. and practical techniques including computer science, information techniques, etc. should also be instructed by means of problem-oriented didactics and practical training skills rather than traditional fields of forestry only. Moreover, the knowledge of modern forestry, natural ecosystems, rural socioeconomic development and practical managerial skills in practical sociology, finance, administration, and staff management should be effectively offered to the nature reserve staff, especially to the managers. Only by doing so, can the workers be qualified and a solid foundation laid for the better biodiversity conservation and utilization.

Conclusion

As biodiversity conservation is a complex system-engineering project that involves so many factors such as natural environment, species evolution, human disturbances, management level, protection intensity, technology supports, etc. The 4 strategies should therefore be implemented in a harmonious way by establishing a beneficial mutual-improvement mechanism. Ecotourism should at first be designed and appraised according to the professional factors called 7As, i.e., Attractions, Access, Amenities, Activities, Affinity, Accommodation and Actors that determine the functions of an entire ecotourist system. It is these 7 factors that determine the prospects of the trade. However, ecotourism is only a professional subsystem in the complex system-engineering project of biodiversity conservation and the 7As involve a background too complicated to ensure a good function of the subsystem alone. It is thus necessary that proper institution innovation including legal, economic, political, administrative and cultural supporting systems be established and perfected. When researching and developing the biodiversity landscape singularity in the peculiar ecotourism, special attention should be paid to the economic globalization tendency. When tapping the existing natural resources, humanity landscape resources should be fully utilized with good protection of the biodiversity. Ecological education and natives' participation in ecotourism as a substitute (Pu *et al.* 2000) for their over-dependence on natural resources should also be stressed in the conservation practice. Attention should be paid to the entireness, comprehensiveness and systematicness of the entire set of the conservation strategies during their implementation. Only by optimizing the 4 innovation strategies in their organic entirety, can a mutual-improvement mechanism be established in a real sense by making the ecotourism harmoniously sustained, local people's livelihood uplifted and biodiversity conservation bettered.

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